MINISTRY OF FORESTS

Review

of the
Timber Supply Analysis Process
for B.C. Timber Supply Areas

Final Report (Volume I)

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Preface

In the spring of 1990, the Executive of the B.C. Forest Service initiated an internal review of the processes leading to the determination of allowable annual cuts for Timber Supply Areas. This report presents the results of that study and its recommendations.

The Forest Service is committed to ensuring that its procedures leading to the determination of AAC are timely and reliable, that appropriate techniques and technology are utilized, and that integrated resource management is supported.

To this end, the Executive has directed that a process to implement the recommendations in this report be immediately put in place, and that an action plan be developed, detailing the tasks to be completed, the associated responsibilities and completion dates. The action plan will require input and participation throughout the Forest Service in order to achieve the recommendations set forth in this report.

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Executive Summary

One of the Forest Service's most important functions is the setting of the rate of harvest, or allowable annual cut (AAC), for the timber resources of British Columbia. This decision is the responsibility of the Chief Forester, as defined in Section 7 of the *Forest Act*.

Allowable annual cuts are determined by the Chief Forester after considering a wide range of social, economic and biological factors; they are not calculated directly from a formula based on biological or technical factors.

Problem

A major source of information for the Chief Forester about the timber production possibilities of a Timber Supply Area (TSA) is the timber supply analysis. Of late, widespread concern from within and outside the Forest Service has been expressed about the quality and validity of this analysis and whether it is sufficiently reliable for use by the Chief Forester in determining the AAC.

To address these concerns, the Forest Service Executive in 1990 initiated an internal review of the procedures and information used in setting allowable cuts. This report describes the primary findings of the review and makes recommendations on the major issues arising out of the investigation.

The review was specific to Timber Supply Areas only, and the issues addressed are those identified by Forest Service staff as areas of concern. In particular, it focused on the quality of timber supply analysis and the AAC determination in light of current Forest Service integrated resource management (IRM) objectives.

Purpose

The purpose of this review was to determine whether the information provided to the Chief Forester to assist in the determination of AACs is appropriate, timely and sufficiently reliable.

Methods

Staff in all Forest Service Regions and some Districts were consulted to obtain their perceptions and opinions about allowable cuts in their areas. Information was gathered in a series of discussion sessions, then carefully compiled and grouped into various issue categories.

The issues were rigorously reviewed by experts within the Forest Service and a team was established to undertake projects dealing with those items considered of greatest importance or concern. Technical, administrative and policy issues were addressed.

Major Findings

The following are the findings from staff interviews and projects which were undertaken as part of this review.

- There is a perception among many staff that allowable annual cuts are too high. This opinion is partly due to philosophical beliefs, public pressure and concern over the quality of timber supply analysis.
- Timber Supply Area timber supply analyses are not being performed rapidly enough to stay current with changes in management procedures and policies.[1]
- Many key personnel at Branch, Region, and District levels have a poor understanding of inventory and timber supply analysis procedures and applications.
- A major shortcoming in timber supply analysis is the failure to fully account for the effects of non-timber values on timber supply. Many staff stated that current AAC levels do not allow for the delivery of sound integrated resource management.
- The potential effects of non-timber values on timber supply are both short- and long-term. While they do not necessarily dictate an immediate reduction in allowable cuts, they may affect the timing and degree of the falldown predicted for most TSAs.
- Many of the analytical and computational procedures used in timber supply analysis, such as inventory data aggregation and computer modelling, are sound. However, some aspects of the derivation and application of the data used in these processes should be revised.
- There is much controversy associated with the growth and yield information used in timber supply analyses. Some staff feel that the potential for future yields is much higher than is currently recognized; however, this view remains in dispute.
- There is inconsistency in the approaches and procedures used in timber supply analysis throughout the province.
- There is a lack of monitoring how well timber supply analysis assumptions and predictions match actual field practices and experience.

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[1]Timber supply analyses used in determining existing AACs often do not adequately reflect current field practices related to integrated resource management objectives.

- Many areas of concern identified by staff have been previously recognized within the Forest Service, and some are already being addressed (e.g., the preparation of new yield functions).
- The Forest Service has lost its leadership in the field of timber supply analysis. This is due, in part, to giving this function a low priority; the Forest Service has not aggressively recruited and maintained its own expertise.

Major Recommendations

- A six-month moratorium should be placed on TSA timber supply analyses and the subsequent revision of AACs pending implementation of the recommendations contained in this report.
- The Forest Service should re-establish its leadership and expertise in timber supply analysis. This is necessary to ensure both staff and public confidence in the determination and appropriateness of AACs.
- The Forest Service should establish a faster and more responsive system for completing timber supply analyses and establishing AACs to keep pace with rapidly-changing forest resource management.
  - Timber supply analyses should be performed and AACs revised for all TSAs over the next three years. They should reflect prevailing management conditions and knowledge.
  - Timber supply analyses should be conducted on a continual basis, such that all TSA AACs are reviewed completely, and **without exception**, at least every five years.
  - Detailed analyses of major issues concerning future proposals and decisions of forest and land management options should continue to be conducted but should not delay the more rapid analyses and subsequent reviews of AACs.
- Appropriate Forest Service staff at all levels should receive mandatory training in inventory and timber supply analysis methods.
- Timber supply analysis capability should be developed in Regions, and eventually Districts. This capability should not replace that of the headquarters timber supply analysis staff.
- Enhancements should be immediately incorporated into timber supply analysis procedures to better account for timber harvesting deferrals, IRM practices, site degradation, economic and spatial operability, and changes in volume estimates that more closely describe the existing growing stock.
- Timber supply analysis should account for future forest land productivity changes that have a high probability of occurring (e.g., for roads and landings).
- The Forest Service should explicitly review and re-define sustained yield units where necessary so that timber supply analysis and field administration operate under similar assumptions.

- The Forest Service should improve its data management in the:
  - monitoring of harvested areas and volumes, and in relating these to timber supply analysis
  - quality control of inventory procedures
  - agreement between forest cover maps and inventory data bases
  - standards for growth and yield projections
- The Forest Service should improve the management and quality control of timber supply analyses to ensure consistent application of assumptions and methods across the province. Sensitivity analysis of important assumptions and inputs should be a routine part of timber supply analysis.
- The Forest Service should accelerate the production of managed stand yield projections for use in TSA timber supply analyses.
- The responsibilities and procedures for the approval and use of stand yield projections for Crown lands should be strengthened and enforced.
- The methods for calculating and interpreting long-run sustained yield should be reviewed and clarified.
- The Forest Service should establish a permanent process for ongoing internal review and audit of inventory and timber supply analysis procedures leading to AAC establishment. Ongoing development of methods and procedures for timber supply analysis must be a priority.
- The findings and recommendations of this review should be distributed to Forest Service staff.

Introduction

As forests serve a growing variety of uses, traditional harvesting levels and methods of timber production are being questioned. Other forest values, such as wilderness, old-growth, recreation and wildlife habitat, compete with timber interests for the same landscapes and often the same forests. To accommodate these interests, the processes by which forests are planned and managed must change.

The rate of harvest is increasingly under scrutiny, along with associated issues of concentration of harvesting and sustainability. Many of the questions to be answered require better and different information than has been used in the past.

The rate of harvest, or allowable annual cut (AAC), is set by the Chief Forester in consideration of a variety of social, economic and biological factors. It is the culmination of a comprehensive planning process that involves Forest Service District, Region and Branch staff, along with representatives from the forest industry and other resource agencies. Steps in this planning process include the identification of issues, gathering of information, analysis, reporting and public review. This procedure is undertaken for the timber, range and recreation resources.

The major input regarding timber production possibilities is obtained through timber supply analysis. This analysis combines forest inventory data, assumptions as to silvicultural regimes and their responses, and integrated resource management objectives (and their implied constraints on timber production).

Recently, concern has been raised by Forest Service staff at all levels about the quality and validity of the information used in and provided by the timber supply analysis, and its adequacy in supporting the determination of AACs. Specific concerns relate to:

- perceptions that AACs may be too high in light of constraints to incorporate new integrated resource management (IRM) objectives and the technical validity of current information and approaches
- the long time period since the most recent timber supply analyses and determination of AACs for the majority of TSAs
- the clear need to ensure that the information provided to the Chief Forester, which leads to AAC determination, is as reliable as possible

To address these concerns, the Forest Service Executive in 1990 requested a review and analysis of staff concerns regarding the determination of AACs.

The purpose of this review was to determine whether the information provided to the Chief Forester to assist in the determination of AACs is appropriate, timely and sufficiently reliable.

Forest Service staff from Branches, Regions and Districts were interviewed to obtain their perceptions and opinions on matters relating to harvesting rates and levels.[2] Each person or group was asked a common series of questions on policy, administration, inventory quality and use, timber supply analysis procedures and field practices leading to the determination of allowable annual cuts for Timber Supply Areas (TSAs).

The concerns identified in the interviews were grouped into four general issue categories:

- forest inventory quality and application
- timber supply analysis procedures
- field practices versus timber supply analysis assumptions
- timber supply analysis policy and administration

Within each of these categories specific concerns were compiled, summarized, and ranked in terms of importance. The ranking considered the frequency with which certain concerns were expressed and their assessed validity.

Studies were designed to address those areas identified as being of greatest concern and that were believed to have the potential for major impacts on the timber supply analysis and the determination of allowable annual cuts. A team of investigators[3] was established to set up projects to investigate those issues of greatest concern.

This review was specific to Timber Supply Areas; Tree Farm License data and procedures were not reviewed.

Most of the projects documented in this report were based on a review of data specific to certain areas. While the results cannot be assumed to apply everywhere, they indicate the existence of problems requiring further study. Overall, there is a need to be more analytical in future timber supply analyses. Table 1 lists the title and a brief description of each project. Further documentation will be provided in a future Project Reports Document giving detailed methods, results and recommendations.

The following pages provide a synthesis of the findings of these projects and staff interviews with respect to key timber supply analysis issues. Appendices I and II list the Forest Service staff involved in the review, and Appendix III contains a discussion of AAC perceptions.

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[2]Appendix I: List of Participants in Region/District Discussion Sessions.

[3]Appendix II: List of Project Participants.

Table 1: Summary of Review Projects

Project Title	Project Objective
Comparison of Forest-Level Optimization and Simulation Techniques	To determine the differences in results which are obtained.
Culmination Age Comparisons	To test for bias in the culmination age resulting from fitting yield curves and to identify the relative stability of mai around culmination age (+/- 5%) mai.
Impact of Applying Average Yields to a Mature Inventory Which Has Been Developed Through a "Best Stands Logged First" Approach	To determine if yields will be seriously overestimated as a result of applying non-biased average yields to a data base which has a biased distribution.
Impact of Re-Inventory on Yield Analysis	To compare the new and old inventory for a TSA and assess the validity of the growth projections and update methods and the effects on yield analyses.
Impact on Yield Analyses of Unaccounted-for Missed Timber Strips Along Creeks, Lakeshores and Other Inaccessible Areas	To determine significance to yield analysis results and provide recommendations for data package preparation.
Provision of Yield Analysis Capability in Regions	To discuss need for and provide recommendations.
Review of Inventory Aggregation in Yield Analyses	To review and suggest improvements to the aggregation process. To test the impact on yield analysis results.
Rotation Age Comparisons	To determine how changes in harvest age affect the wood supply forecasts.
Scale to Inventory Comparisons	To determine the accuracy of the total yield projection system. If consistent problems are found, to document short- and long-term solutions.
Setting AACs on a Smaller Area Basis	To determine the impact of setting AAC on a sub-TSA basis.
Site Degradation and Long-Term Productivity Losses	To ensure that long-term productivity losses are in the correct order of magnitude in yield analysis.
Site Index Assignment for Early Immature Stands	To document the existing system for estimating site index for young stands (<30 yrs.) and check for bias.
Site Index Conversion and the Assignment of the Mid-Point of Inventory Attributes	To test the existing methods for bias in attribute assignment.
The Impact of Deferrals and Harvest Pattern Restrictions Which are not Accounted for in Yield Analyses	To determine how sensitive yield analyses are to these; and to provide short-term and long-term recommendations.
Timeliness of Yield Analysis Procedures	To discuss need for and provide recommendations.
Training in Inventory Procedures and Forest-Level Concepts	To discuss need for and provide recommendations.
Use of Cruise Information to Supplement the Inventory	To discuss the concept and complexity.
Validation of the MUSYC Generator and Report Writer	To identify which version of MUSYC is most reliable and to trace and correct any coding problems on that version.

Issues, Findings and Recommendations

Throughout the Forest Service, concern was expressed about timber supply analysis and current allowable cuts. All participants were supportive of the review process and many provided additional documentation of their concerns, technical papers and new insights. Forest Service staff are clearly committed to improving timber supply analysis capabilities and procedures within the Ministry.

Almost all Forest Service staff are concerned that the current processes that lead to the establishment of an AAC overestimate timber supply. Some of this opinion can be traced to perceptions and beliefs regarding AAC, long-run sustained yield (LRSY) and timber supply. These perceptions are discussed more fully in Appendix III. Other sources of concern relate to:

- technical problems with the inventory estimates (e.g., loss factors, volume estimates and yield projections)
- the failure of timber supply analysis to adequately incorporate the harvesting restrictions necessary to accommodate non-timber values
- the need to complete timber supply analyses and update AACs in many TSAs (existing AACs for many TSAs are based on outdated analyses)
- the discrepancy between forest management assumptions made in timber supply analyses and actual harvesting operations (e.g., operability, accessibility, utilization, regeneration delay)

There was also a significant variation in the level of understanding of forest inventory and timber supply analysis techniques and applications by staff at all levels.

In the following pages the major issues identified in the staff interviews are introduced. For each issue, the findings from interviews and subsequent investigations are summarized. Accompanying each finding is one or more recommendations on how to proceed with respect to this issue.

Timeliness of Timber Supply Analyses, Analysis Assumptions and Current Management Practices

Existing AACs are based upon analyses and assumptions that do not adequately reflect current management practices. This may be the result of a change in management practices since the last timber supply analysis, or of inadequacies in the timber supply analysis to capture the effects of current management practices.

Findings:

The most recent timber supply analyses for most TSAs are outdated.

- In the last 8 years, only 13 of 35 TSAs have completed analyses leading to new AACs.
- The conditions on which assumptions were based in those analyses (e.g., for land base, environmentally sensitive areas, deferrals) have changed considerably and have typically become more restrictive to the timber supply. In addition, there is new information to be incorporated, such as revised inventory information and new basic silviculture objectives and practices.
- The time currently taken for timber supply analyses is so long that the assumptions on which the analyses are based may have changed by the time the analysis is completed.
- The impacts of these elements (i.e., changing conditions, information and assumptions) on timber supply estimates are neither clear nor consistent -- their effects could be positive, negative, short-term or long-term.

Recommendation:

1 The Forest Service should establish a permanent and expeditious system for the completion of timber supply analyses and the determination of allowable cuts to keep pace with rapidly-changing forest resource management in B.C.

- Expeditious timber supply analyses should be performed and allowable cuts re-established for all TSAs over the next three years. These analyses should be conducted and treated as "technical updates" that will incorporate current information on inventory, growth and yield, deferrals, land base assumptions, present management practices and government policy.
- The technical update timber supply analysis (hereafter referred to as the technical update analysis) should reflect prevailing conditions and knowledge as well as those land use issues or other forest management decisions that have been resolved through the appropriate processes (e.g., approved Local Resource Use Plans (LRUPs)). The technical update analysis is, therefore, a reflection of the *status quo*; new issues should not be introduced.

- To improve the degree to which AACs are in concert with current management practices, technical update analyses and reviews of allowable cuts should be conducted on a continuous basis, so that the province is completely reviewed at least every five years.
- The technical update analysis is not a substitute for the more complex and time-consuming analysis that the Forest Service has used in recent years in its TSA planning process. Therefore, while the results of technical update analyses should be made available to the public, the analyses themselves should not require in-depth public involvement; this is undertaken through the more comprehensive timber supply analysis carried out in support of TSA planning.
- The more comprehensive TSA planning process, which defines issues and management options, remains critical to Forest Service planning; it sets the big picture within which all timber supply analyses are done. It also provides for the public review of major issues concerning future proposals and decisions on forest and land management options. Land use and forest management decisions emanating from the TSA planning process may themselves lead to a review of AACs. Regardless, they would be incorporated in subsequent technical update timber supply analyses.
- The TSA planning process and associated resource analyses take place over a much longer period than the technical update timber supply analysis and should not impede the progress of the technical update analysis.

Findings:

Deferrals and harvest pattern restrictions have a significant effect on the timber supply in some TSAs and these impacts are not adequately accounted for in current timber supply analyses.[4]

- LRSY estimates were reduced from 2% to 7% as a result of delayed rotation ages arising from deferrals and harvest pattern restrictions in three areas studied. Such restrictions also cause short-term interruptions in wood flows. While these effects do not dictate an immediate reduction in allowable cuts, they may affect the timing and degree of the falldown that is predicted for most TSAs.

The areas studied represent a range of conditions and it is likely that the results will apply to other areas of the province.

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[4]Restrictions on harvesting patterns are imposed to maintain wildlife habitat and meet LRUP constraints and visual quality objectives.

Recommendation:

2 Immediate technical enhancements should be made to the timber supply analysis system to better account for timber harvesting deferrals (restrictions in harvest pattern and levels to accommodate non-timber values). While initial enhancements may involve temporary approximations to enable immediate solutions and analysis, more comprehensive analytical methods should be developed in the long term.

Findings:

Some areas of timber strips left for purposes such as streamside or lakeside buffers, or that occur in small inaccessible pockets, are not accounted for in timber supply analysis. While the extent of these areas is difficult to estimate, they may represent as much as 3% of a total TSA in extreme cases.[5] As these areas are unlikely to be harvested under present conditions, they should not be considered as part of the forest land base contributing to AACs.

Recommendation:

3 Techniques should be developed to provide consistent accounting of small areas of inaccessible or unmerchantable timber not otherwise accounted for in timber supply analysis.

Findings:

Studies in eastern B.C. indicate that site degradation on logged areas may reduce LRSY by 10 to 20%.[6] This is in addition to the long-term timber supply reductions associated with road and landing construction. The effects of site degradation are not reflected in current timber supply analysis.

Site degradation effects on timber supply are long-term and will not be felt until second-rotation harvests take place. There is little consensus in the scientific community about how best to estimate the actual impact, and further analysis is required.

Recommendation:

4 The Forest Service should derive estimates of the long-term productivity losses associated with site degradation and develop procedures to routinely incorporate such loss estimates into timber supply analysis.

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[5]This value was estimated based on ocular review of satellite imagery and staff input.

[6] E.g., Thompson, 1988; Utzig and Walmsley, 1988.

Findings:

The accounting for long-term productivity losses due to permanent road and landing construction has been handled inconsistently in the past. Current deductions range from 0.1% to 12%, though it is unlikely that the true range is this large. Moreover, a review of long-term productivity losses recorded in silviculture history records shows that, on a provincial average, roads and landings productivity losses are being underestimated by 5%.[7]

Since the analyses of the early 1980s did not fully account for these factors, those TSAs that have not undergone recent timber supply analysis can expect a reduction in LRSY.

Presently, deductions are made only to account for road and landing developments that have already occurred. Anticipated reductions to the productive timber base for roads and landings are not reflected in timber supply analyses.[8] This can lead to an overestimation of timber supply.

Recommendations:

5 The estimation of long-term losses due to roads and landings should be improved, and should make more use of silviculture history information. Deductions for roads and landings should be applied more consistently across the province.

6 Timber supply analysis should account for future productivity changes that have a high probability of occurring (such as for roads and landings) since these could affect short-term or long-term timber supplies.

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[7] This point is more fully described in the Project Reports Document on roads and landings deductions.

[8] E.g., even those in approved development plans.

Definition of Sustained Yield Units

In current TSA timber supply analyses, the TSA is assumed to be the sustained-yield unit. However, in many areas, the trend is to administer smaller sustainable units, such as operating areas for licensees and local resource use plans.

Findings:

Local resource use and watershed planning exercises exemplify the trend to manage timber supply on smaller sustained-yield units than the traditional TSAs. Where the units are too small, or contain stands which are predominantly immature or predominantly mature, flexibility in maintaining harvest flows and other forest management objectives will be reduced and timber supply deficits will occur in the short- to medium-term until broader stand age-class distribution exists. A move towards achieving sustainable timber supplies from smaller areas may result in a fall in the total provincial timber supply.

Recommendations:

7 Studies should be undertaken to ascertain the conditions under which a reduction in the size of sustained-yield units will lead to timber supply difficulties.

8 In the meantime, the Forest Service should explicitly review and, if necessary, re-define its sustained-yield units or otherwise ensure that timber supply analysis, field administration and management operate under common assumptions.

9 Wherever local sustainability of timber supply is an issue, timber supply analyses should reflect this, and timber supply analysis, the determination of AAC and the administration of forestry activities should be linked.

Projections of Future Stand Yields

Confusion exists around the subject of stand yield projections, and there are wide-ranging expectations about future timber yields associated with managed forests. The Science Council of British Columbia (1990) has indicated that doubling the yields from B.C. forests is an achievable objective; many silviculturists agree. However, without data of sufficient authority to support these claims, the subject of future yields remains speculative.

Findings:

This is an area that is poorly understood, subject to uncertainty and about which there is more opinion than fact. There are different methods of constructing yield projections, a bewildering array of stand yield projection models, unclear objectives for the use and application of yield projections, and little appreciation for their reliability and precision.

There is much speculation within the forestry community on potential future yields. Many forest managers feel that improved stand management (e.g., optimal stocking levels with genetically superior stock, thinning, fertilization) will increase future yields dramatically.

Currently, approved managed stand yield projections are not widely available for all commercial B.C. species. While the demand for such information is extremely high, there is no apparent consensus within the sector regarding the responsibility and approval process through which to pursue managed stand yield projections.

A review of the potential for future yield gains in one interior TSA is found in the Project Reports Document. While potential yield gains are indicated, they are modest compared to popular opinion and are not all associated with intensive stand management. Moreover, many of the gains projected are based primarily upon professional judgment, rather than on data from permanent sample plot records.

Recommendations:

10 The Forest Service should improve its management of the development of stand yield projections.
   - Formal procedures and standards for the development of yield projections should be promoted and followed within the Forest Service, and communicated throughout the forest sector to encourage the growth and yield community to work together more closely. The Forest Productivity Councils of B.C. could have a role in the review and approval process.
   - The level of uncertainty surrounding stand yield projections should be determined and clearly explained.

- Routine sensitivity analysis of yield projections to changes in yield model assumptions should be undertaken.

11 Managed stand yield projections should be completed for all commercial B.C. species as soon as possible.

12 Collection and acquisition of permanent sample plot data should be a priority within the province.

13 Research Branch, in close consultation with other Branches and programs within the Forest Service, should prepare a discussion paper on the process for developing managed stand yield projections. This document should clearly articulate the authorities and process for approval, and note the Chief Forester's prerogative to approve stand yield projections and consider only approved stand yield projections during a timber supply analysis.

Accounting for Fragmentation

The impacts of fragmentation and the dispersal of merchantable stands is not well accounted for in forest estate modelling.

Current forest estate modelling techniques do not recognize the geographic distribution of the forest inventory information being analyzed. Stands with similar attributes are grouped together in total area and then modelled in aggregate over the planning horizon. There are concerns that this approach will produce more optimistic results than can actually be achieved in the field.

Findings:

In certain areas, failure to account for stand dispersal and distribution can cause timber supply analysis results to be optimistic. This is a case of modelling techniques not adequately reflecting operational conditions.

A TSA that has extremely heterogeneous forest cover distribution (e.g., immature mature, merchantable and non-merchantable stands occurring in patchwork across broad areas) can be easily misrepresented during timber supply analysis because of the aggregation process. While the aggregate inventory can show a positive timber supply, the actual availability of these stands in the short-term can be limited due to physical or other constraints on accessibility.

Williams and Gasson (1987) pointed out that the short-term availability of forests in coastal British Columbia is very sensitive to market conditions. Walker (1983,1986) also emphasized the importance of stand dispersal to short-term volume availability and scheduling, and developed economic criteria to use in association with modelling for timber availability.

In the past, when yield calculations were done using Hanzlik's formula, the final step was to conduct an area/volume allotment check. This was a crude attempt to reconcile the long-term analysis with the short-term in order to demonstrate whether there was sufficient short-term volume available at certain proposed levels of harvest. More recently, the approach has been to conduct a twenty-year operating area review whereby field staff confirm the availability of at least a twenty-year supply of timber at the proposed AAC. This is done prior to the Chief Forester's determination of the allowable cut.

A review indicates that this has not been done consistently in recent years, if at all. In some areas, a very sophisticated, technical approach has been used; in others, the instincts of planners and field staff have been used to make this determination. Given the sensitivity of this concern, consistent procedures must be used in each TSA.

Recommendations:

14 There should be a renewed commitment to the verification of a short-term, twenty-year timber supply. This is perhaps the simplest way of handling the uncertainty of stand dispersal, development costs and merchantability.

15 The current initiative to upgrade the Forest Service's analysis capability (TSAS-II)[9] should be reviewed to ensure that the system addresses the dispersal problem.

16 Clear minimum standards for the confirmation of short-term volume availability should be established and enforced.

17 As technical capabilities improve, methods should be developed to handle the massive amounts of information contained in a geographic inventory data base in order to facilitate the modelling of this issue.

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[9]The Timber Supply Analysis System Version II is a proposed revision to the current timber supply analysis system. It is area-based, with a primary focus on the short-term planning problem (i.e., finding timber on the ground for the first 20 years) and is intended to be implemented as a planning support system in the Regions and Districts.

Monitoring Changes to the Inventory

Currently, there is no monitoring to compare actual harvest, scale and cruise volume estimates with inventory and timber supply analysis volume estimates. Nor is there monitoring of the change in average stand volumes in the remaining inventory, where higher volume stands have been logged first.

Findings:

In some TSAs the scale volume summaries from harvested areas differ significantly from inventory volume estimates.[10] Timber supply projections may, as a result, be unreliable.

Recommendation:

18 Systematic procedures should be established where the actual volume harvested (including waste and breakage) is monitored and compared with inventory volume estimates. This would provide a continual check on the validity of inventory volume estimates, decay, waste and breakage loss factors, scaling procedures and, ultimately, timber supply projections.

Findings:

Cutting permit cruise information is not currently used to check, supplement and enhance the inventory data base (for volume estimation), though the issue has received much study in the past. The problem is essentially one of sampling bias: cruise samples are intensive and located in stands selected for logging, whereas inventory samples are located more extensively across a Timber Supply Area. Data standards also differ. Procedures are presently being developed to reconcile these differences.

Cruise data could provide an efficient means of upgrading inventory data. It could also provide a tool to reconcile any bias that exists from using the inventory samples to estimate the declining average volumes of existing mature stands.

Recommendation:

19 Cutting permit cruise data should be used to monitor inventory and timber supply analysis estimates and should be incorporated into the inventory data base, where it can be determined that it does not introduce bias.

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[10]Possible reasons for these differences may be poor utilization and waste accounting; inaccurate inventory volume estimates; inaccurate decay, waste and breakage loss factors; or faulty scaling procedures.

Findings:

Average yield estimates are used to describe stand volumes. However, where higher volume stands are harvested first, the remaining stands no longer represent average stand volumes. This can lead to overestimation of the volume in the remaining mature inventory.

A study of three TSAs revealed differences in the volumes from logged and unlogged forest inventory sample plots. The potential range of differences was estimated to be as high as 20% for the TSAs studied.

In a timber supply analysis this may affect the short-term harvest schedule and the estimation of the timing, rate and severity of the falldown. Estimates of long-term AACs should not be affected, if all other assumptions remain the same.

Recommendation:

20 Where possible, the degree to which the inventory volume estimates represent the existing stocks of mature volume should be quantified and incorporated in timber supply analyses for short-term volume projections.

Long-Run Sustained Yield (LRSY)

There are differing views on what the LRSY is and what yield potential it does or should represent.

Findings:

The LRSY reported in Forest Service documents is the product of a simple calculation based on the maximum average annual growth ("culmination mai") of a stand.

Using culmination mai to estimate LRSY provides an optimistic view of potential future yields. First, it assumes that the maximum merchantable volume yields are achieved on 100% of harvested sites. Second, it assumes that all stands will be logged at or near the time at which the growth of the stand culminates. Due to biological factors (e.g., growth rates, weather) and management realities (e.g., harvesting deferrals), neither of these assumptions is realistic.

Further, there is no clear policy on whether the LRSY benchmark should be based on current management practices or based on what might be achievable in the future.

Recommendations:

21 Policy should be developed that clearly defines how the LRSY is calculated and what it is intended to represent.

- The LRSY could be defined based on current management practices. This would mean using average yields at expected rotation age, rather than at culmination age, in the cases where these differ.[11]
- The term "maximum sustainable yield" (MSY) could be used to define the potential yields that could be achieved where stands are harvested exactly at the age of culmination.[12]
- Careful thought should be given to which set of stand yield projections is used in defining LRSY and MSY in view of the potential to overestimate yields when using managed stand yield projections versus natural stand yields.[13]

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[11]This would overcome the concern of projecting a LRSY based on the assumption of pure yield maximization when in fact current and projected field practices will not allow this to happen. This will produce values lower than current LRSYs.

[12]This definition would have the benefit of indicating the potential of the land base without implying that this will be achieved in practice.

[13]Is it realistic to assume that 100% of logged sites will be managed to their fullest potential? Further consideration of this point may cause the LRSY and MSY definitions referenced above to be further differentiated.

Understanding Timber Supply Analysis

Forest Service staff require better understanding of forest inventory, growth and yield, and timber supply analysis procedures.

Findings:

The objectives of the forest inventory and the level of detail to which it applies are not fully understood. Staff contributing to the data package used in timber supply analysis could benefit from a better understanding of the analysis procedures that use this information. Forest-level and stand-level concepts also require attention. Staff effectiveness and efficiency in timber supply analysis could be improved by better training and support.

Recommendation:

22 Appropriate Forest Service staff at all levels should receive mandatory training in inventory, growth and yield, and timber supply analysis methods.

- This training should be non-technical; its intent should be to develop understanding of concepts and procedures, not to provide technical details of the models used.
- Training in inventory concepts should focus on the purpose, accuracy, reliability and appropriate application of B.C.'s forest inventory.
- Training in timber supply analysis methods should focus on improving the understanding of forest-level and timber supply concepts, and the procedures used for AAC determination in B.C.
- Training for timber supply analysis staff should be ongoing to strengthen their skills in timber supply modelling and analysis concepts and, in doing so, to better support continued development and review of timber supply analysis techniques.
- Timber supply staff from Headquarters should have a greater presence in Regions and Districts to implement training and to obtain an improved understanding of local issues.

Findings:

Inventory Branch data bases are of several types, vintages and data standards; and details on these are poorly documented. Computing procedures that are developed to use inventory data will not necessarily work universally. This situation has created difficulties for those not familiar with changes in data standards that have taken place over time.

Recommendations:

23 The Forest Service should improve its inventory procedures, specifically in the quality control of inventory procedures and the agreement between forest cover maps and inventory data bases.

24 A manual of inventory data management procedures and standards should be developed for Forest Service staff. This manual should be systematically updated as changes take place. While much documentation already exists, it should be packaged appropriately and distributed thoroughly.

Findings:

Errors in inventory compilations are often not found until after data has been distributed. These errors seem to be due to a lack of quality control procedures and insufficient staff time available for quality control.

Recommendation:

25 The Forest Service should establish quality control procedures for inventory data compilation.

Findings:

Errors in timber supply analysis computations are often not found until after results have been distributed. These errors seem to be a result of insufficient quality control procedures and insufficient time for timber supply analysis staff to devote to the analysis of a particular TSA.

Sensitivity analysis of changes in timber supply model results with changes in assumptions is only partially performed during timber supply analyses by testing additional "scenarios."

Recommendations:

26 The Forest Service should improve the management and quality control in its timber supply analyses.

27 A manual of methods, standards and procedures should be developed for timber supply analysis. While primarily for Forest Service staff, it should be made available to other interested individuals.

28 Timber supply analysis staff should be provided with sufficient resources to support individual TSA timber supply analyses, and should be encouraged to become more analytical in exploring timber supply issues.

29 Procedures should be developed for routine sensitivity analysis of the changes in timber supply analysis results due to changes in assumptions.

Responsiveness of Timber Supply Analysis

Timber supply issues periodically arise that require rapid analysis. Integrated Resources Branch staff are often unable to respond to these because of work loads. Many issues could be addressed through analyses of an informal and exploratory nature within the Regions or Districts, if the appropriate training and tools were provided. Currently, the regional and district implications of timber supply-related issues are often not quantified and sometimes not well-understood.

Findings:

There is presently no consistent capability to perform timber supply analyses in Forest Service Regions and Districts though staff want to perform some of these functions and have a closer involvement in the timber supply modelling process for their areas.

Recommendation:

30 The capability to perform timber supply analyses should be developed in Forest Service Regions and Districts.

- This will help to improve understanding of local timber supply, enable faster response to timber supply issues as they surface and result in more efficient and better quality major TSA timber supply analyses. It will strengthen Forest Service expertise in the areas of growth and yield and timber supply analysis, and provide career alternatives associated with timber supply analysis at various work sites. In the long run, this will be an important step in increasing the profile of timber supply analysis, the resident level of expertise and the quality of the analysis.
- Additional staff positions will be required in Regions.

This capability **should not** replace that of the Headquarters timber supply analysis staff.

- It is imperative that the Chief Forester permanently maintains a team of proficient timber supply analysis foresters in the Forestry Division.
- The duties of this Headquarters team should be to develop improved techniques, ensure consistency of application in Regions and Districts, and provide training on an ongoing basis.

  It should maintain the responsibility for the regular, major and comprehensive timber supply analyses that lead to the establishment of allowable cuts for TSAs. This task could be made more effective and efficient by using the analysis work conducted by Regional and District staff through their modelling and analysis initiatives.
- Headquarters staff should also liaise with the timber supply analysis and growth and yield community outside of the Forest Service to improve management and control of this important issue.

Validity of Timber Supply Analysis

The validity of Forest Service timber supply analyses is being challenged.

Findings:

Recent timber supply analyses done by groups outside the Forest Service challenge the validity of those done by the Forest Service. These external analyses imply that Forest Service data is poor and that procedures are, in some cases, wrong. Such analyses have the potential to result in unsolicited lobbying and pressure to influence the Chief Forester's AAC decisions.

Recommendations:

31 The Forest Service should reaffirm its position of leadership and control in establishing and maintaining timber supply analysis standards, responsibilities, and expertise for the province.

- Both inventory and growth and yield components should be included.
- A team of experts should be established with the responsibility to adjudicate growth and yield issues.

32 A single Forest Service responsibility centre should be established for all timber supply and timber supply analysis matters.

- The timber supply analysis group should be moved from the current Integrated Resources Branch reporting structure into its own Section with a manager. The analysis group should retain a strong staff (team) relationship with the planning side of Integrated Resources Branch.
- Due to the complexity of timber supply analysis and the low numbers of "resident experts" in this field, the organization of this Section must consider career paths and succession planning in order to attract and retain qualified staff.

Inventory Data Aggregation

Inventory data aggregation procedures are believed to significantly affect the results of timber supply analyses.

Findings:

The process by which inventory data is aggregated for timber supply analyses does not, in most cases, significantly alter the inventory description. Moreover, timber supply model results have a low sensitivity to the degree to which data is aggregated.

However, there are circumstances in which aggregated inventory summaries may differ to an unacceptable degree from those for disaggregated inventory data bases (e.g., where the degree of aggregation is extreme or the aggregation units are not judiciously chosen). While these conditions are believed to be infrequent, procedures are needed to ensure that these cases are identified so they can be dealt with.

Recommendations:

33 Procedures should be developed wherein routine comparisons are made between pre- and post-aggregated inventory data summaries. Where an aggregated summary differs to an unacceptable degree, the aggregation strategy should be reviewed and revised until an acceptable aggregated inventory data base is derived.

34 Alternatives to present methods of aggregation should be investigated. Approaches that increase timber supply model complexity and reduce the ease of analysis and interpretation should be avoided.

Culmination Age

Confusion exists around using the age of culmination of mean annual increment as the desired rotation age in timber supply analyses. It is not clear how precise the estimates of culmination taken from Forest Service stand yield projections are, nor how sensitive timber supply analysis results are to changes in culmination age changes.

Findings:

The imprecision of present estimates of the age of culmination of mean annual increment (based on existing stand yield projections) was not determined during this review due to time and resource constraints.

Recommendation:

35 The lack of precision in present estimates of the age of culmination of mean annual increment should be determined so that the validity of stand yield projections and timber supply forecasts can be assessed.

Findings:

In general, changes in allowable harvest age ranges in timber supply models do not have a major impact on LRSY or predicted long-term harvest schedules. This is true so long as the ranges contain the rotation ages that have been used to define LRSY. However, depending upon the age distribution of timber, they can have a significant impact on estimates of the short- to medium-term harvest schedules by restricting the timber that is considered old enough for harvesting. Where harvesting is strictly limited by the age of timber, then the model's harvest age assumptions and the sensitivity of results to changes in assumptions should be carefully considered.

Recommendation:

36 Sensitivity analysis of harvest age ranges should be conducted during timber supply analyses.

Site Index Bias

Averaging site index across all age classes during the aggregation of inventory data may create a consistent upward bias in resulting stand yield projections.

Findings:

Analysis conducted during this review has shown that this does not appear to be the case.

Recommendation:

None.

Bias Associated with Mid-point Values

The assignment of midpoint values for site index and age during inventory classification procedures introduces bias.

Findings:

Analysis shows that this does not appear to be the case. Assigned midpoints appear to provide good representation of average conditions for inventory samples.

Recommendation:

None.

Inventory Update

Inventory data may be updated through projection of older vintage survey data or through field re-inventory and re-compilation. The latter method is assumed to be more reliable, however the differences in reliability between the two methods and the timber supply analysis implications are not well understood. This makes it difficult to assess the importance of major re-inventory requirements.

Findings:

The differences in inventory summaries resulting from inventory projection techniques versus complete re-inventory and re-compilation were not assessed due to time and resource restrictions.

Recommendation:

37 The differences in inventory summaries resulting from inventory projection techniques versus complete re-inventory and re-compilation should be quantified for units where results from both techniques are available. This review should be conducted as subsequent TSA re-inventories are completed.

Optimization or Simulation

There is confusion about the possible differences in timber supply projections that can be obtained from either forest optimization timber supply models[14] used in B.C. or simulation models.

Findings:

There are no major differences in the underlying concepts and behaviour of forest-level optimization and simulation models when they use the same data and assumptions. Each technique can assist forest planners in reaching the same conclusions, though each has certain advantages that may render it more suitable for addressing certain questions. Often, they are best used in concert.

To date, B.C. Forest Service timber supply analyses have relied almost solely on optimization techniques.

Recommendation:

38 The Forest Service should make more balanced use of simulation and optimization timber supply models at all levels of TSA timber supply analyses.

MUSYC

The MUSYC model was intended to be an interim model for U.S. Forest Service use as other approaches were developed. As a result, it was never fully developed and tested. This has caused uncertainty regarding the reliability of results obtained using that model.

Findings:

The MUSYC model has undergone thorough review in areas that have been suspected of producing incorrect results. While computer programming errors have been uncovered, it has been confirmed that these errors have not affected the information provided to the Chief Forester. The errors were associated with some seldom-used reports produced by MUSYC and resulted in these reports sometimes being incorrect. The actual solutions for LRSY and harvest schedule were unaffected. These errors have been corrected.

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[14]E.g., the U.S. Forest Service (USFS) timber supply model MUSYC (Multiple Use Sustained Yield Calculation).

While no longer used by the U.S. Forest Service, the MUSYC model used by the B.C. Forest Service has been upgraded more than once and is an excellent timber supply modelling tool. The model still requires a more complete documentation of its features and enhancements.

Recommendation:

39 The more complete documentation of the MUSYC model features and enhancements should be finished.

Other Recommendations

40 The findings and recommendations of this review process should be disseminated to Forest Service staff.

41 The Forest Service should establish a permanent process for continuing internal review and audit of inventory and timber supply analysis procedures leading to AAC establishment.

42 Timber supply analysis development should be given a higher priority and development should be ongoing. Topics requiring immediate attention include:

- Review of TSAS-II to incorporate the findings of this study.
- Improvements to existing models or the acquisition/development of new models to incorporate such aspects as:
  - spatial considerations in harvesting (deferrals, etc.)
  - AAC and operating area allocation
  - fire and pest impacts

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Appendix I
List of Participants in Forest Service Staff Discussion Sessions

Office	Name
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	Tom Lewis
	Rob MacDonald
	Phil Van Mol
	Yukio Ozawa
Clearwater District	Elia Ganderski
Kamloops District	Bob Miller
Merritt District	Don Embury
Salmon Arm District	Gil Kirke
Nelson Region	Greg Rowe
	Cal Hauk
	Terry Peter
Arrow District	Ken Arnett
	Ted Evans
Golden District	Larry Price
Kootenay Lake District	Al Bradley
	Reg Davis
Prince George Region	Glen Baber
	Rod Baumbach
	Boyd Brown
	Ken Collingwood
	Leverne Merkel
	Dick Nakatsu
	Darrell Robb
	Rich Truant
	Howard Willis
Prince George District	Maury Drage
	Jeff Burrows
	Rick Siempelkamp

Office	Name
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Prince Rupert Region	Janet Gagne Graeme Hynd Gary Lloyd Gary Miltenberger Neil Nesting
Bulkley District	Sally Lebeter Barry Smith
Kalum District	Brian Downie Glenn Smith
Kispiox District	Michael Geisler Andre Germain
Morice District	Ivan Listar
North Coast District	Philip Madeley
Vancouver Region	Nelson Harrison John Howe Ken Ingram Gerry Kennah Gary Sutherland Rich Scarrow
Chilliwack District	Vic Doerksen
Squamish District	Ken Blom
Forest Service Executive	John Cuthbert, Chief Forester
Information Systems Branch	John Ellis
Integrated Resources Branch	Jack Biickert James Crover Tom Hall Alf Kivari Andrea Lang Al Niezen Bruce Sieffert Dave Waddell

Office	Name
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Protection Branch	Val Fletcher Peter Fuglem John Muir
Research Branch	Lois Dellert
Silviculture Branch	Robin Brown Mike Wyeth
Timber Harvesting Branch	Gail Brewer Julius Juhasz

Appendix II
List of Project Participants

Name	Office
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Reg Davies	Kootenay Lakes District
Rob Drummond	Inventory Branch
Darrell Errico	Research Branch
Ken Freed	100 Mile District
Christine Galliazzo	Lillooet District
Alf Kivari	Integrated Resources Branch
Andrea Lang	Integrated Resources Branch
Wayne Nedoborski	Arrow District
Larry Pedersen	Cariboo Region
Ken Richardson	Inventory Branch
Darrell Robb	Prince George Region
Glenn Smith	Kalum District
Jon Vivian	Inventory Branch
David Waddell	Integrated Resources Branch

Appendix III
Discussion of AAC Perceptions

During interviews conducted with Forest Service staff in the course of this review, a common feeling expressed was that allowable annual cuts were too high. This discussion will attempt to provide some background and perspective to these perceptions.[15]

In British Columbia, the AAC is selected by the Chief Forester of the province. The choice results from the consideration of social, economic, philosophical and technical issues and is not the result of a numerical calculation based on technical or biological factors.[16]

The AAC reflects a broad-based consideration of resource values and management objectives within each Timber Supply Area. The analysis of timber supply is but one consideration. Consequently, there is no "correct" level of harvest for a TSA; rather, there is an appropriate AAC that reflects the capabilities of the land base and prevailing social values.

To better illustrate the choices facing the Chief Forester, it is useful to review the timber supply for a typical B.C. Timber Supply Area. Timber supply within a TSA can be displayed as a harvest schedule, as shown in Figure 1.

A forest has some upper limit of productive capacity for a variety of products and uses. In terms of timber this is often described in the form of a long-run sustained yield (LRSY). In B.C. this is a theoretical upper limit of what could be harvested on a regular basis if a number of conditions (such as appropriate age distribution, complete accessibility, no uncertainty in stand growth, etc.) are met.

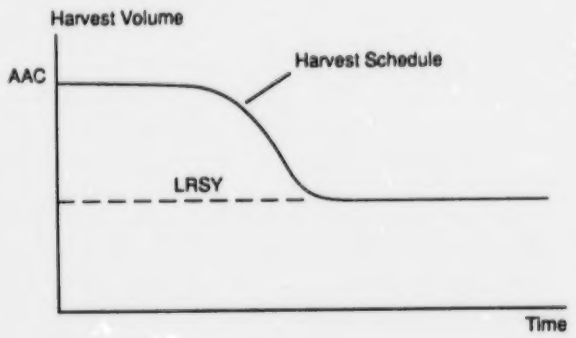

Fig. 1 A typical harvest forecast for a B.C. TSA attempts to sustain the AAC for as long as possible before declining to LRSY.

[15]For a good discussion on these and other aspects on AAC policy and perceptions see Williams (1990).

[16]This is one of the most misunderstood concepts regarding the determination of AAC. Many believe that AAC is simply the result of a technical calculation based upon strict rules, and that it is therefore obliged to change in response to changes in the variables included in that calculation.

LRSY is calculated as the sum of the maximum production rates of each stand in the forest multiplied by its area. The maximum rate of production for a stand is its maximum mean annual increment (mai). The maximum mai represents the maximum achievable growth rate of a stand type and is associated with a particular rotation length. Managing for a shorter or longer rotation will yield a different (lower) mai.

LRSY is also a maximum, and any departure from the assumptions of optimum rotation lead to a lower value.[17]

Since LRSY is a maximum rate of production, any AAC above LRSY cannot be maintained indefinitely. Eventually it must fall, at least to the LRSY level, and often lower.

Allowable annual cut levels are currently set above the LRSY in most TSAs. It is possible to harvest at these levels because of the abundance of old, high-volume stocks of timber. However, this will eventually lead to a "falldown", which can take a variety of forms, differing in timing and severity. It is the Forest Service's intention that the falldown be regulated so that AACs drop gradually until they reach the long run sustained yield.

The perception that AACs are too high relates primarily to:

- the poor understanding by many of the concept of LRSY, the differences between LRSY and AAC, and B.C.'s sustained-yield policy
- the belief by many that allowable cuts are obliged to rise or fall according to rigid rules or calculations

Where there are reductions or increases to the LRSY (e.g., for land base withdrawals or other changes in management practices), many believe that the AAC should be reduced or raised accordingly. For the case where LRSY declines, Figure 2 shows that lowering the AAC by an amount equal to the drop in LRSY results in a parallel, lower harvest schedule. Falldown still occurs, from the new (reduced) AAC to the new (reduced) LRSY.

Alternatively, Figure 3 illustrates the policy of maintaining the AAC at its current level, but with the effect of having the falldown occur sooner and more dramatically than under the original harvest schedule.

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[17]One should not place too much importance on the concept of optimum rotations, since the ability to manage at a strict rotation is theoretical only. In the implementation of harvest operations many restrictions would prevent a stand harvest from occurring at an age which is very close to the optimum. This has an impact on the ability to achieve estimates of maximum mean annual increment and LRSY.

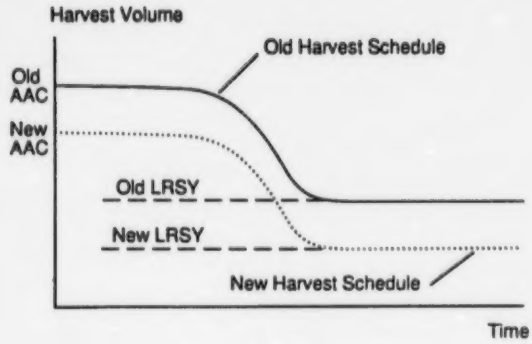

Fig. 2 A reduction in LRSY requires an adjustment to the harvest schedule.

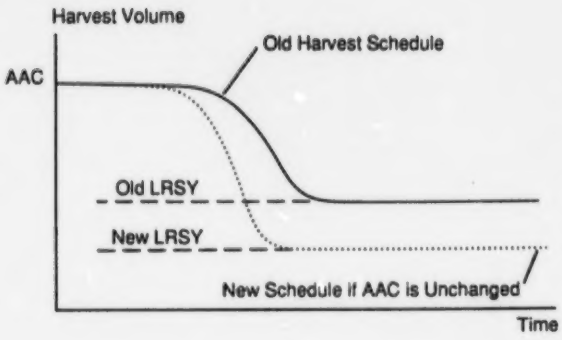

Fig. 3 The AAC may be sustained despite a drop in LRSY, with the implication of more severe adjustment sometime in the future.

Between these two extremes lie a range of AACs that might be chosen, with varying consequences. Thus, there is no right or wrong AAC. The purpose of the timber supply analysis is to provide the Chief Forester with an estimate of the implications of different AACs to assist in determining the most appropriate AAC for a particular TSA.

Another contribution to the perception that allowable cuts are too high is the conviction that the AAC should be equal to LRSY to provide an even-flow output from forests and thereby maintain the stability of those economies dependent upon the forest industry. While much has been written on this subject, the literature does not conclude that an even-flow yield regulation policy guarantees community stability, nor that community stability cannot occur in the absence of an even-flow policy.[18]

A decision to lower or raise AACs is made only after careful consideration and is based upon stronger social, economic and biological reasons than the dictates of tradition. Among the diverse, and often conflicting, factors considered are: present community reliance on the forest industry, a harvest flow that does not drop below LRSY in the future, maximizing returns from the timber resource and maximizing benefits from other forest resource uses.

Concerns about current AACs and the timber supply analysis process have precipitated a desire to sustain existing levels of harvest on a more local basis than the TSA. The Forest Service and industry may wish to maintain perpetual operating areas, while communities may wish to maintain either sustained levels of harvest or a sustained forest environment in "their" portion of the TSA.

However, the sustained-yield unit upon which current allowable cuts are established is the TSA (for most Crown land) and one of the important assumptions underlying the

[18] E.g., Byron, 1978;Waggener, 1977; Shallau, 1989.

established AAC is that there will be flexibility in the movement of harvest operations within the TSA. In the past, there has been no attempt to ensure a continual harvest in TSA sub-units. In those sub-units where there are insufficient stocks of mature timber to allow indefinite harvesting at present levels, operations must relocate elsewhere on the TSA if they are to maintain their present level of harvesting.

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Appendix IV
Glossary

Culmination age is the age at which a stand reaches its maximum mean annual increment. It is the age commonly used to indicate the age of maximum volume production of a stand and its readiness for harvesting.

Forest planning models are analytical (usually computer-based) models which successively harvest and grow collections of forest stands over a period of several decades according to specific data and management assumptions. See also forest estate simulation models and linear programming harvest scheduling models.

Forest estate simulation models address "what-if" questions by simulating a specified policy or management alternative.

Fragmentation refers to the dispersion of merchantable stands arising from inoperable site conditions or unmerchantable species compositions, from harvesting and other forestry operations, or from the clearing of forests for other land uses.

Harvest forecast is a measure of timber supply, usually the maximum timber supply that can be realized over time from a land base, under specified management assumptions. It is an output of forest planning models and is a function of the size and productivity of the land base, the current growing stock, the length of the planning horizon and the totality of management objectives, constraints and assumptions and how these are modelled.

Inventory data aggregation is the aggregation of stand-level forest inventory data into summary strata for use in timber supply models.

Inventory projection is the process of accounting for all of the accruals and depletions to a forest inventory from the present to some future date.

Linear programming harvest scheduling models seek out the policy or management alternative that optimizes the attainment of a specified management objective, subject to specified management constraints.

Long-run sustained yield (LRSY) is a measure of land base productivity for specified management assumptions, or the maximum volume of timber that can be produced on a continuing basis in perpetuity from lands being managed for timber production. LRSY can be thought of as the MSY of a land base, adjusted upwards or downwards by the imposition of management objectives and constraints on the land base.

Long-term refers to the period covering more than one rotation, commonly 200 years.

Maximum sustainable yield (MSY) is a measure of land base productivity. The MSY for a land base is the sum of the product of the maximum mai (based on empirical yield projections to specified diameter limits and utilization standards) and the land area for each major timber type.

Mean annual increment (mai) is the average annual increase in volume of individual trees or stands (i.e., stand volume divided by stand age). The mai changes with different growth phases in a tree's life, being highest in the middle years and then slowly decreasing with age.

Optimization models are computer models that determine a harvest schedule that optimizes some criterion (e.g., maximizing timber production, minimizing cost).

Options are sets of assumptions representing possible management directions, constructed as a normal part of a planning process in order to provide a framework for analysis and facilitate management decision-making.

Planning horizon is the time frame addressed in a plan or in analyses carried out in support of a plan. A planning horizon usually includes a "look-ahead" period which is required to understand resource dynamics and provide a basis for evaluating alternatives, and a "detailed" period which is needed to lay out management guidelines and provide a basis for operational decision-making.

Sensitivity analysis determines the change in the harvest schedule that is caused by changes in data. (E.g., one might examine the sensitivity of the first decade harvest to changes in the availability of old-growth timber.)

Short-term is the period covering the next 20 years.

Site index is a measure of site productivity based on tree height as a function of stand age, and is usually expressed graphically as site index curves. Site index curves have been developed for B.C.'s major commercial tree species.

Timber supply analysis is the assessment of future timber supplies over long planning horizons (200 years). Timber supply analyses are carried out using forest planning models for the different scenarios identified in the TSA (or TFL) planning process.

TSA planning process is the process of planning and developing a forest management plan for a timber supply area (TSA) as set out in the Forest Service *Resource Planning Manual*. The TSA Plan establishes the long-term objectives and the broad management strategies for the timber, range and recreation resources in the TSA. For the timber resource, the TSA Plan establishes an allowable annual cut (AAC) and 20-year licensee operating areas.

Technical update analysis is the frequent, technical update of timber supply analyses carried out at least once every five years and as issues arise which could potentially affect timber supply (e.g., changes in land use allocation or inventory status). The technical update is an analysis exercise rather than a planning exercise, and takes place within the overall comprehensive resource planning of a timber supply area.

Yield projections are forecasts of future yields from forest stands or timber types. Yield projections can be developed for stand volume, stand diameter or specified products, and for empirical (average stocking), normal (optimal stocking), or managed stands.